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DIFFRACTION BY A SCREENED CHIRAL LAYER WITH A GRATING

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ABSTRACT

Polarization characteristics of the reflecting structure like a chiral layer combined with a dielectric layer, both in between a diffraction grating and a screen, are considered. Due to the analytical regularization procedure derived from the Riemann-Hilbert problem method, the correspondent diffraction vector problem is solved in the form available for effective numerical treatment. The numerical investigation shows a number of the new diffraction features caused by the chiral medium presence.

INTRODUCTION

A chiral inclusion can do more than vary one or another characteristic of the system, which takes it in. In cases, it imparts novel properties even to well-known structures, for example a cross-polarized component in the reflected field of a linearly polarized wave incident normally on an ordinary strip grating, attached to the isotropic chiral half space [1]. In view of the circular polarization of the chiral medium eigenwaves and due to the boundary conditions, the chiral medium binds both linear polarizations. On the one hand, this gives rise to the new interesting effects, but on the other hand it complicates the problem, which becomes then a vector one.

PROBLEM FORMULATION AND SOLUTION

The structure of interest is shown in Fig.1. A half-space $h_1 < z$ is a dielectric characterized by permittivity ε_1 and permeability μ_1 . The dielectric layer ($0 < z < h_1$) with the constitutive parameters ε_2, μ_2 and the chiral one ($-h_2 < z < 0$) with ε_3, μ_3 and the chirality parameter γ are placed between the perfectly conducting screen ($z = -h_2$) and the grating ($z = h_1$) composed by infinitely thin and perfectly conducting strips parallel to the OX axis. The grating period is l , the slot width is d .

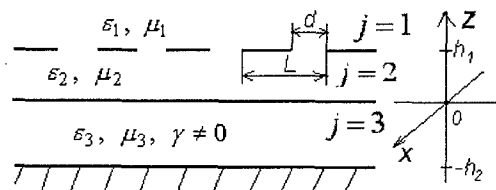


Fig.1. The structure profile.

The wave $\mathbf{E}^i = \mathbf{E}_0 \exp(i(\mathbf{k}^i \mathbf{r} - \omega t))$, $\mathbf{H}^i = \mathbf{H}_0 \exp(i(\mathbf{k}^i \mathbf{r} - \omega t))$ with $\mathbf{E}_0 = (\tilde{e}, 0, 0)$ and $\mathbf{H}_0 = (\tilde{h}, 0, 0)$ (\tilde{e}, \tilde{h} are complex) is obliquely incident on the grating so that

$\mathbf{k}^i = -2\pi\sqrt{\varepsilon_1\mu_1}/\lambda_0 \times (0, \sin\alpha, \cos\alpha)$, where α is the angle between the incident wave vector \mathbf{k}^i and the OZ axis. We seek to find the diffracted field.

In so far as the incident field is x -independent and the grating extends infinitely in the x direction, the problem can be solved in two-dimensional terms ($\partial/\partial x \equiv 0$). For existence and uniqueness of the solution, the conditions [2] to satisfy are: Maxwell's equations; radiation condition; boundary conditions; quasiperiodicity condition, and condition of the field energy finiteness. For the considered two-dimensional problem, the field in the homogeneous chiral medium looks like [3]

$$\mathbf{E} = \mathbf{E}^+ + \mathbf{E}^-, \quad \mathbf{H} = \mathbf{H}^+ + \mathbf{H}^- = -i(\mathbf{E}^+ - \mathbf{E}^-)/\rho_3,$$

$$\Delta_{yz}u^\pm + k^\pm u^\pm = 0, \quad E_x^\pm = u^\pm(y, z), \quad k^\pm E_y^\pm = \mp \partial u^\pm / \partial z, \quad k^\pm E_z^\pm = \pm \partial u^\pm / \partial y,$$

where $k^\pm = -k_3(1 \pm \eta)$, $k_j = \omega\sqrt{\varepsilon_0\varepsilon_j\mu_0\mu_j}$, $\eta = \gamma/\sqrt{\varepsilon_3\mu_3}$, $\rho_j = \sqrt{\mu_0\mu_j/\varepsilon_0\varepsilon_j}$. Thus all the field components are expressed through the E_x^\pm . The eigenwaves are right and left

circularly polarized waves with the propagation constants k^\pm . The discussed problem requires vector approach because the sought fields have all the components.

In view of that the medium interfaces coincide with the coordinate planes, our approach to this boundary problem solution is by the method of separation of variables. Anticipating existence of the solution, the grating periodicity along the OY axis enables the problem solution to be expanded into Fourier series for each structural region.

Substitution the series in Helmholtz equation ($\Delta_{yz}u + k_j^2u = 0$ for the $j=1,2$ domains

and $\Delta_{yz}u^\pm + k^\pm u^\pm = 0$ for $j=3$) gives the field representation, which coincides with

the Rayleigh expansion of the diffracted field as an infinite series of partial waves of spatial spectrum. The wave propagation character is clear from the obtained field representation: the propagation constants of the n -harmonic are $\xi_n = 2\pi n/l - k_1 \sin\alpha$ along

the OY axis and $\zeta_n^j|_{j \neq 3} = \sqrt{(k_j)^2 - (\xi_n)^2}$, $\zeta_n^\pm|_{j=3} = \sqrt{(k^\pm)^2 - (\xi_n)^2}$, $(\text{Im}\zeta_n^{j,\pm} \geq 0)$ along

OZ . The wave complex amplitudes are unknown Fourier coefficients.

Applying the boundary conditions to each surface one can relate the sought Fourier coefficients in the partial domains and obtain the two coupled systems of dual series equations involving trigonometric functions. The obtained systems are equivalent to an operator equation of the first kind in the Hilbert space given by the Meixner condition [2]. These systems are ill-conditioned, therefore the truncation technique is generally unappreciable. The analytical regularization can help us to get rid of this ill-conditioning and arrive at the form admitting effective numerical and analytical treatment [2,4].

NUMERICAL RESULTS

Introduce the structure efficiency in the n -order of spectrum R_n^x, R_n^y , which determines the relative part of scattered energy spread from the structure to the upper half-space by

the traveling n -harmonic ($\zeta_n^1 > 0$) with the wave vector $\mathbf{k}_n^1 = (0, \xi_n, \zeta_n^1)$. The upper indexes respectively relate to the field of E- and H- polarizations (E-polarization when $\mathbf{E} \parallel OX$ and H-polarization when $\mathbf{H} \parallel OX$). Let us call major polarization that of incidence, then the cross one is that normal to it. The values R_0^x, R_0^y as a functions of $\chi = l/\lambda_0$ and $H_2 = h_2/l$ are represented in Fig.2.

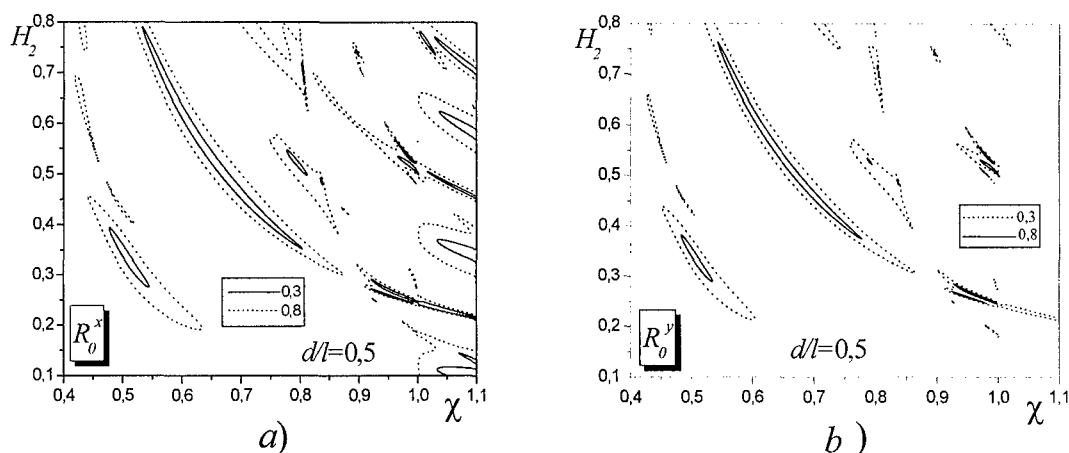


Fig.2 Efficiency in the 0-order of spectrum:
a-main polarization; b-cross polarization

($\tilde{\epsilon} = 1, \tilde{h} = 0, \alpha = 0^\circ, h_1/l = 0.03, \epsilon_1 = 1, \epsilon_2 = \epsilon_3 = 4, \mu_j = 1, \gamma = 0.3$).

CONCLUSION

The analytical regularization procedure for solving the vector problem considered has been constructed. Our approach based on the Riemann-Hilbert problem method lends as a reliable and effective tool. An incident plane-polarized field can be totally converted into the regularly reflected cross-polarized field. The character of the polarization conversion is influenced by the grating and by the resonance properties of the grating-screen volume. The laws of the polarization conversion have been established as well as the possibilities for the enhancement of the structure efficiency and broadbandness.

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